Compact SOI-Based Polarization Diversity Wavelength De-multiplexer Circuit Using Two Symmetric AWGs.

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Abstract *We demonstrate a compact* 16-*channel* 200GHz *polarization diversity wavelength de-multiplexer circuit using two silicon AWGs and 2D grating couplers. Insertion loss and crosstalk are* 2.6dB *and* 21.5dB*, respectively. The maximum polarization dependent wavelength shift is* 0.115nm. *The total circuit size is* 1400X850µm^2*.*

Introduction

In Silicon-on-insulator (SOI) the high contrast submicron waveguide and the tight bends allows very compact components within photonics integrated circuits. This gives more flexibility for the integration of many functionalities on a single chip. But the high contrast waveguides are inherently polarization dependent. As a result also devices such as Arrayed Waveguide Grating de-multiplexers (AWG)[1], one of the typical integrated Wavelength Division Multiplexing (WDM) components in telecom network become polarization dependent. So one of the limitations of the SOI AWGs is that it works only for a single polarization. This is difficult to combine with inputs from standard single-mode fibers with an unknown and variable polarization state.

Polarization-independent waveguides in silicon are difficult to make. Therefore, the commonly accepted approach to achieve a polarization independent circuit is the polarization diversity scheme[2]: The unknown fiber polarizations are split into two orthogonal polarizations which can be used separately in two identical single-polarization circuits. The key challenge for this scheme is to realized two completely identical circuits, which requires a highly accurate fabrication process or active tuning or trimming. In some cases, the polarization diversity circuit with two AWGs can be replaced by a single AWG used in both directions[3]. But this is not always possible and introduces additional loss and back reflection in the fiber. Therefore, in this paper we demonstrate a compact SOI-based polarization diversity wavelength de-multiplexer circuit using two symmetric AWGs and a compact 2-D grating coupler, which is used to couple the unknown fiber polarization into the two separate waveguides by splitting the light in two orthogonal polarizations.

Design of the 2D grating Coupler

In our SOI photonic circuit we use fiber grating couplers to couple the light into the circuit and to couple out from the circuit. As the circuit works for a single polarization (typically TE in the waveguide) the normal 1-D fiber grating couplers can couple only a single fiber polarization (TE, or TM, depending on the design of the 1-D grating). A 2-D fiber grating coupler can couple both fiber polarizations by splitting them into the TE modes of two orthogonally oriented waveguides. Vice versa, the 2-D grating coupler can couple the light back

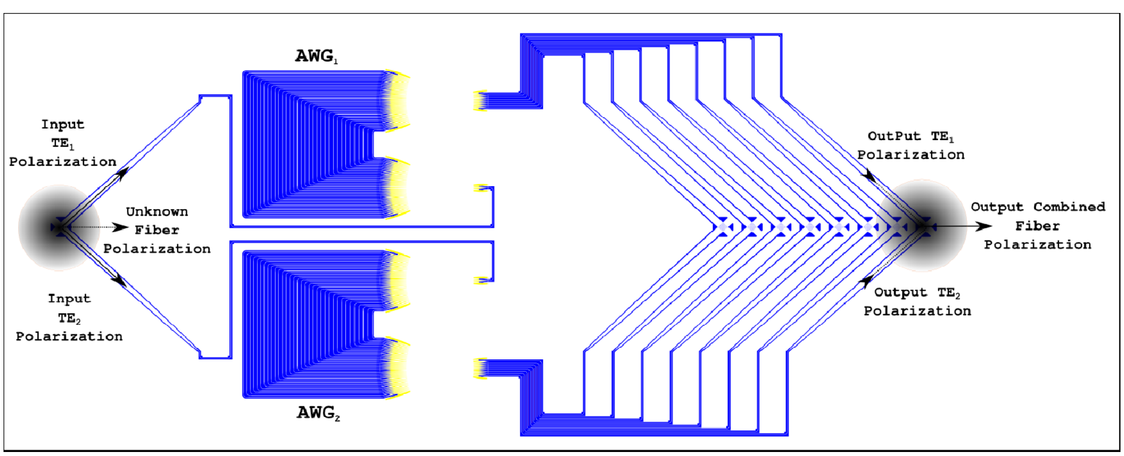

Fig. 1: A schematic diagram of 8 channels polarization diversity wavelength de-multiplexer circuit.

into the fiber by combining the two TE modes into orthogonal fiber modes. This splitter/ combiner functionality[4] of 2-D grating couplers allows us to drive two identical circuits separately to achieve polarization independent functionality.

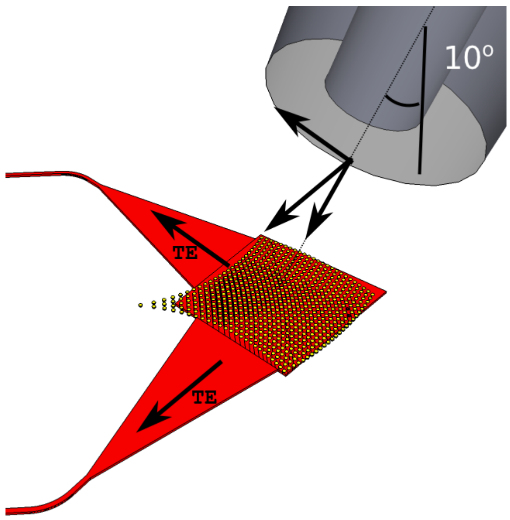

Fig. 2: A schematic diagram of a 2-D grating coupler.

Figure 2 shows the schematic diagram of a 2-D focusing grating coupler. The use of the 2-D focusing grating coupler reduces the taper length of the access waveguide compare to the stander 2-D grating coupler[6]. The fiber is placed vertically over the grating with 10º tilt to avoid the 2nd order reflection back into the fiber. The 2-D grating couplers are etched 70nm into a 220nm thick silicon slab. The access waveguides are fully etched. The diameter of the grating holes are 390nm and the pitch of the grating is 610nm.

The 2-D gratings are not linear, but the grating lines are curved: this focuses the coupled light directly into a 500nm wide wire waveguide over a distance of only 30µm. This eliminates the need for a separate taper.

Design of the AWG

In SOI, due to the high index contrast which allows for tight bends, it is possible to design very compact Arrayed waveguide Grating devices (AWG). But the high contrast makes the waveguide also very sensitive to phase errors, and as a result a typical SOI AWG has higher crosstalk compared to AWGs in the low index contrast material systems. The main origin of phase errors is the sidewall roughness of the delay lines in the array. To reduce this phase error we use broad 800nm-wide waveguides instead of 450nm wide single mode waveguides. To avoid multi-mode mixing inside the 800nm wide waveguides we taper down to 450nm width in the bends. To reduce the reflection from the interface with the star-couplers we used a shallow etched aperture of 2µm wide[5].

We designed two 16 channels AWGs with 72 waveguides in the waveguide array as the basis of our polarization diversity circuit. The channel spacing is 200GHz (1.6nm). The size of the single AWG is 365X650µm^2.

Measurement

To compare the performance of the circuits for both fiber polarizations we excite the circuit separately with a fixed fiber polarization. To control the fiber polarization we connect our tunable laser to a polarization controller. We use a known 1-D TE grating coupler to calibrate the fiber polarization. This gives us the angles of the polarization controller to set an absolute polarization reference at the end of the fiber. We align our fiber on top of the grating using a X-Y-Z moveable stage by actively maximizing the transmitted power. For this, we use a fully automatic alignment setup which allows us to align the fiber with the accuracy of 0.5µm.

Analysis of the 2D grating Coupler

We map the transmission of the 2-D grating coupler by scanning the output fiber over the grating coupler in a 2-D pattern, when the input fiber is fixed at the maximum transmission position. The maximum transmission position of the output fiber for TE fiber polarization is taken as the origin (0, 0), shown in Figure 3. The scanning is done for the 1550nm wavelength of the input laser. From Figure 3 we can observe that the power drops by 2dB if the fiber moves 4µm away from the center. To compare the transmission mapping for TE and TM fiber polarization we keep the alignment of the fiber for TE and then map for the TM which is shown in Figure 3 red line. As we can see from the Figure 3 the transmission mapping for the TM fiber polarization is slightly shifted from the TE polarization map. The smallest blue and red areas shown in Figure 3 indicate the area where the transmission for the TE and TM mode fiber polarization drops less than 0.1dB from their maximum transmission and we can see there is an overlap between the two. Note that this plot is wavelength dependent, and that the points of maximum transmission for the two polarizations move further apart away from the grating's peak

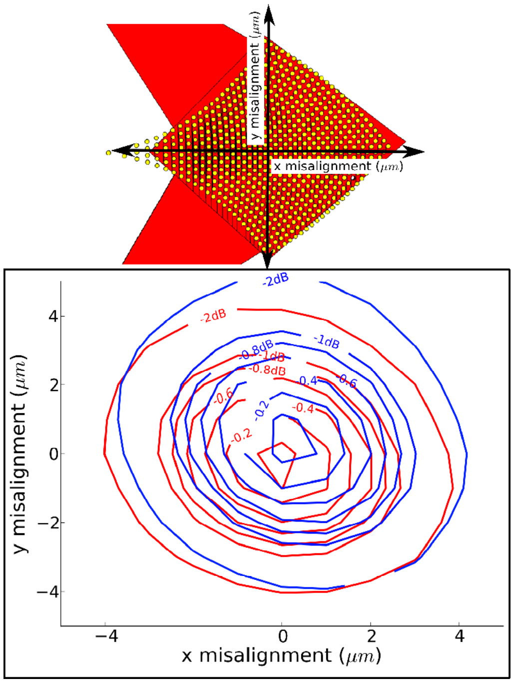

Fig. 3: Experimental comparison of the transmission mapping a 2-D grating coupler for TE (blue circle) and TM (red circle)-mode fiber polarization.

wavelength. Figure 4 shows the transmission of the reference waveguide connected with the 2-D

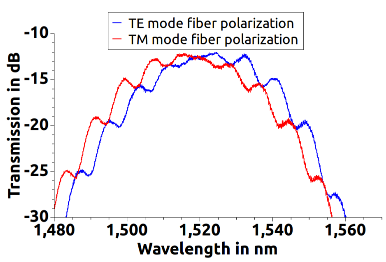

Fig. 4: Transmission of the reference waveguide connected with 2-D grating couplers

grating couplers. For some wavelengths the transmission spectrums don't overlap for TE and TM fiber polarizations, which is the main source of the polarization dependent loss (PDL) in this circuit. The measured PDL of the 2-D grating

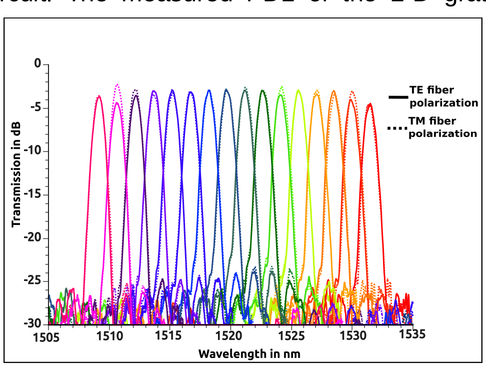

Fig. 5: Spectral response of the polarization diversity circuit for the TE and TM fiber polarization

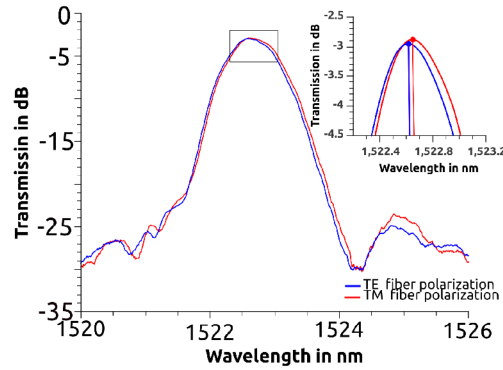

Fig. 6: Spectral response of 9th wavelength channel for TE and TM fiber polarization

coupler is 1.1dB at the wavelength of 1520nm, at which wavelength we measure the maximum coupling efficiency. The PDL can be further improved by positioning the fibers but it will introduce extra loss.

Analysis of full Polarization Diversity Circuit

Figure 5 shows the spectral response of the 16 channels 200GHz polarization diversity wave-length de-multiplexer circuit after normalizing out the spectral response of the 2-D grating coupler. The center channel has an insertion loss of -2.6dB and the crosstalk of the circuit is 21.5dB. The mismatch between the two fabricated AWGs induces a polarization-dependent wave-length shift. This shift is measured to be bet-ween 0.115nm &0.001nm depending on the channel Figure 6 shows the spectral response of the 9th wavelength channel for the TE and TM fiber polarizations, where the shift is 0.03nm only.

Conclusion

We demonstrate a 16X200 GHz polarization diversity wavelength de-multiplexer circuit. The insertion loss and crosstalk are -2.6dB and 21.5 dB respectively. The circuit experience polarization dependent loss of 1.1dB. The polarization dependent wavelength shift varies between 0.115nm&.001 nm over the 16 channels.

Acknowledgement

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